SC options for low energy part of Project X linac

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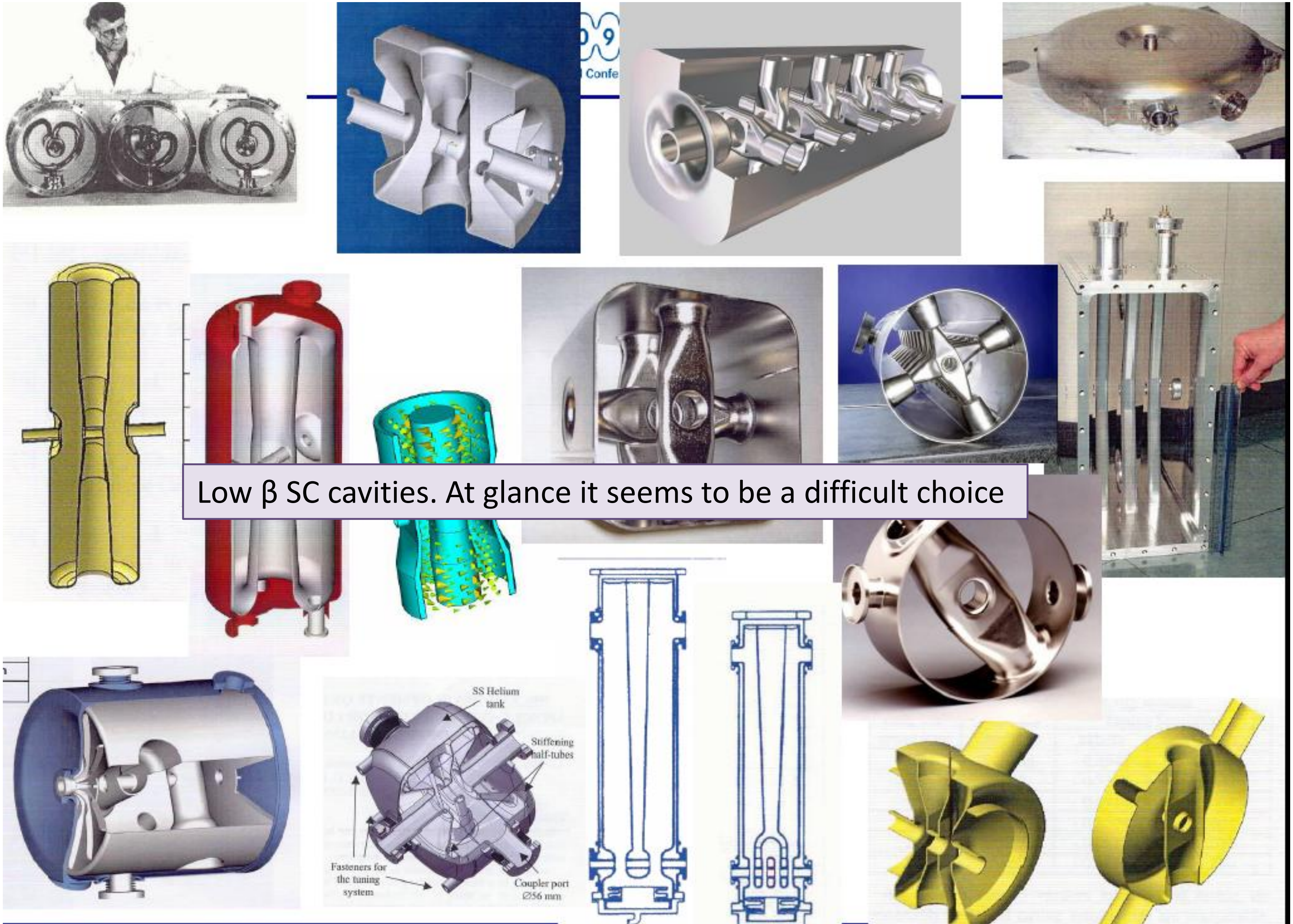
The same problem five years later

General layout of proton driver front end. Variants.

RFQ,0.5-3 MeV	MEBT, chopper?	3-10 Mev, Acc. Str.?	10 – 400 MeV, Spoke
SNS, 402.5 MHz, 2.5 MeV JHF, 324 MHz, 3 MeV	SNS, traveling wave JHF, standing wave low Q cavity Laser chopper. Power? Chopper at higher energy?	Single spoke, $\beta = 0.12$? Half wave cavity. ? DTL Quad. focus.? SDTL Effectiveness? Individual cryostat for each SC solenoids? Some new RT cavity ??	Beyond 10 MeV linac has no apparent fundamental problems **Today is known as SSR0** **Today is known as RT CH. That time we chose them.**

7/28/2004



Low β SC cavities. At glance it seems to be a difficult choice

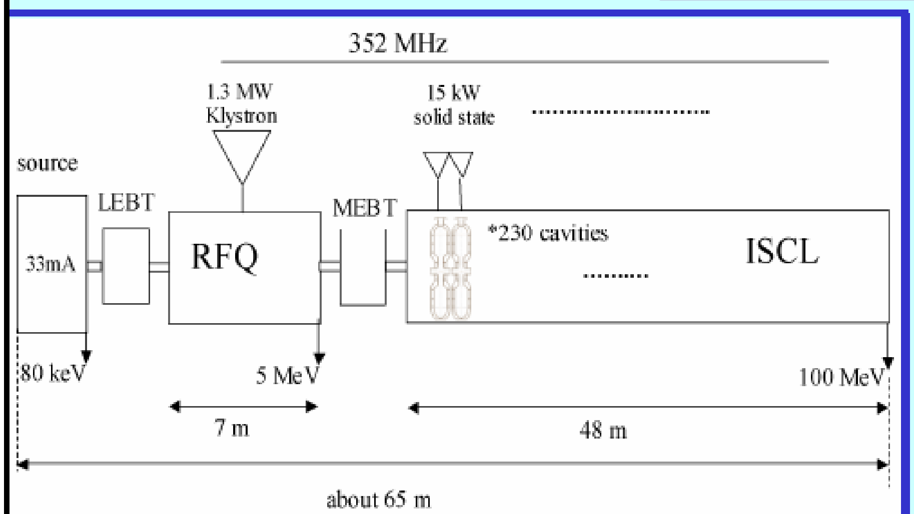
Some facts for consideration. May be not correlated directly.

- All RFQs have output energy > 5 MeV or short RT part after RFQ. The only exception – SARAF with 1.5 MeV after RFQ.
- Beam dynamics imposes constraints on the maximum accelerating field, and thus one of the advantages of SC technology is lost. And more cavities are needed.
- Beam dynamics requires short focusing periods. It creates severe space limitations. Increasing of the drift length between cavities can decrease the separatrix area by several times.
- Short independently phased cavities provide variable beam velocity profile and fault tolerance. But each of them requires own RF control system. Additionally the effective longitudinal emittance grows with the number of resonators as $\sqrt{n[\langle\delta\varphi\rangle^2+\langle\delta A\rangle^2]}$ due to RF amplitude δA and phase δϕ instabilities.
- The RF defocusing term is proportional to frequency, so the lower frequency is preferable. In other hand the shunt impedance considerations aim to the highest possible frequency.

LNL β>0.1, 352 MHz Reentrant cavity

+ Highly symmetric field
+ Very Compact
+ Low Ep and Bp
+ Widest velocity acceptance
+ Possibility of large aperture
- little E gain
- mechanical stability
- inductive couplers only
-ancillaries not yet fully developed

Tested – 8 MV/m, no beam acceleration



TRASCO 30 mA Fault tolerant Linac with Reentrant Cavities

- 5÷ 100 MeV
- 230 cavities
- Cavity aperture 30 mm
- Superconducting quadrupole singlets in a FODO lattice

- SC Linac length : 48 m

HW Ladder resonator

+ large energy gain
+ they can be made for rather low β
+ + easy access (removable side walls)

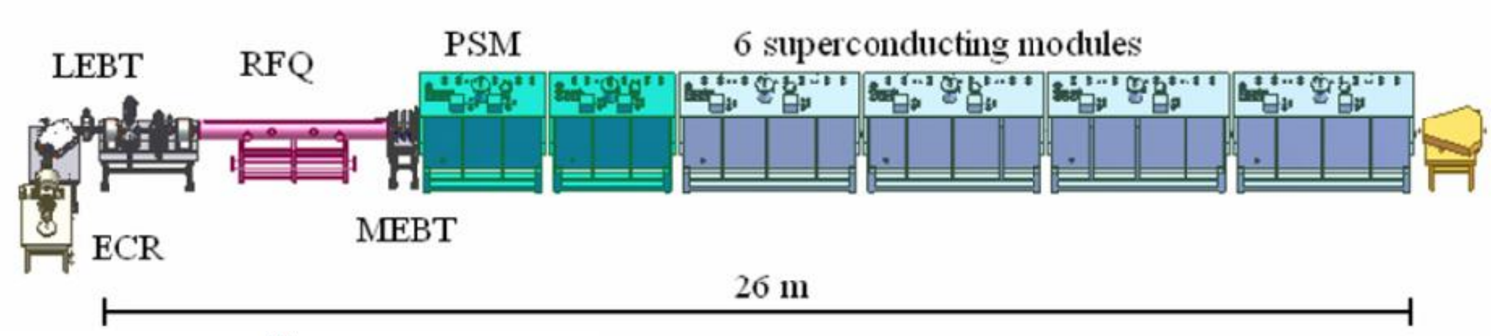
- small aperture
- not easy to build
- strong field emission
-ancillaries not yet fully developed

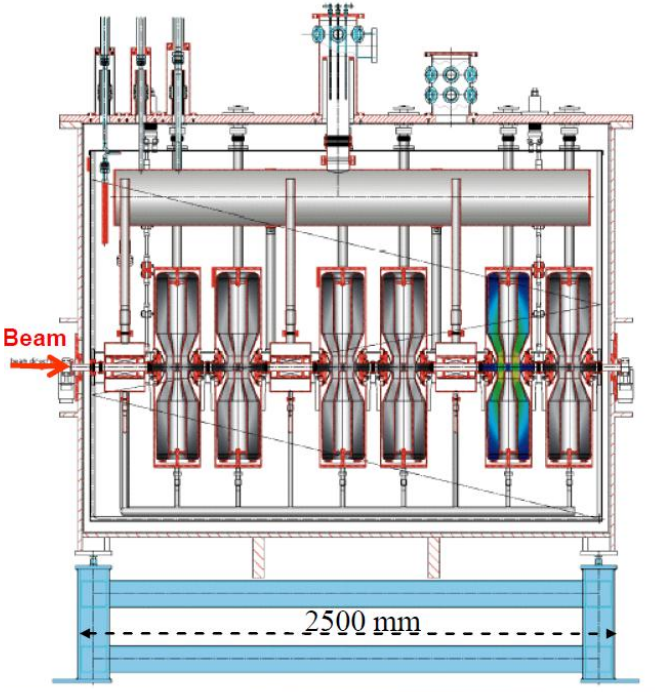
Under development. It's promising for beam boosting just after RFQ. Tested – 5 MV/m. No beam acceleration

A 4-gap Ladder Resonator has been developed at INFN Legnaro for β=0.12 and f=352 MHz.

HW Coaxial resonator

Soreq Applied Research Accelerator Facility



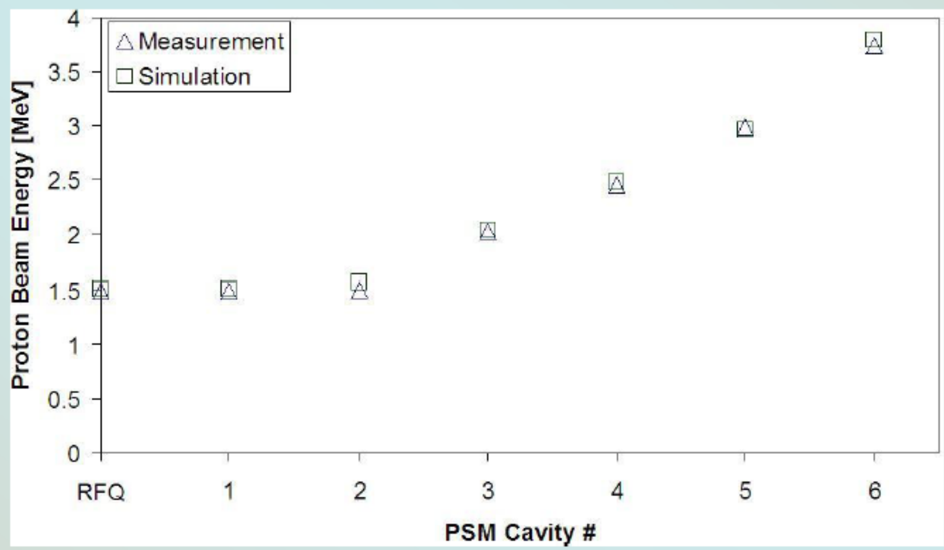


- Houses 6 176 MHz b=0.09 HWRs and 3 sc solenoids
- Accelerates protons from 1.5 MeV
- Very compact design in longitudinal direction
- CW operation
- Specific beam dynamic (KONUS-like)
- For beam simulation TRACK was used

Proton beam – fields, phases, beam energy

- Synchronous phase was found for each cavity by maximizing energy
- Fields, phases and magnet currents were set according to simulations
- The first cavity is used for bunching
- Energy was measured by ToF and compared to simulations

HWR	V_{acc} [kV]	E_{peak} [MV/m]	E_{acc} [MV/m]	Sync. Phase [deg]
1	150	4.5	0.9	-95
2	85	2.6	0.5	0
3	700	21.0	4.3	0
4	550	16.5	3.4	-20
5	550	16.5	3.4	-20
6	900	27.0	5.6	-20



Superconducting CH cavity

Gap number	7
Length (mm)	550
Frequency (MHz)	325
β	0.158
E_p/E_a ($\beta\lambda$-definition)	5.1
B_p/E_a [mT/(MV/m)]	13
$G=R_sQ_0$ (Ω)	64
R_a/Q (Ω) (T incl.)	1250
$(R_a/Q)G$ (Ω^2)	80000
Q_0 (BCS, 4.2K, 325 MHz)	$1.9\text{x}10^9$
Static tuner	4
Bellow tuner	2

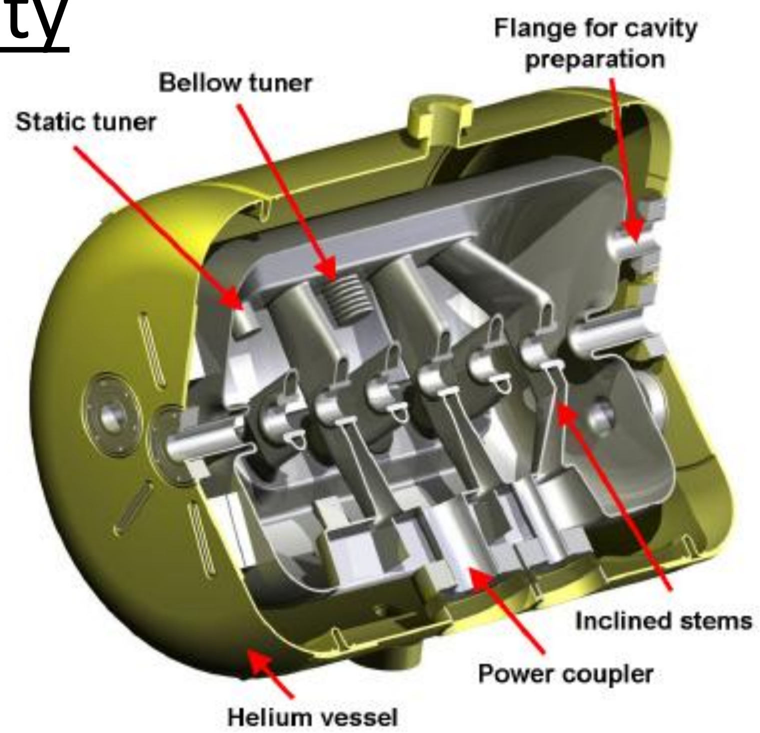
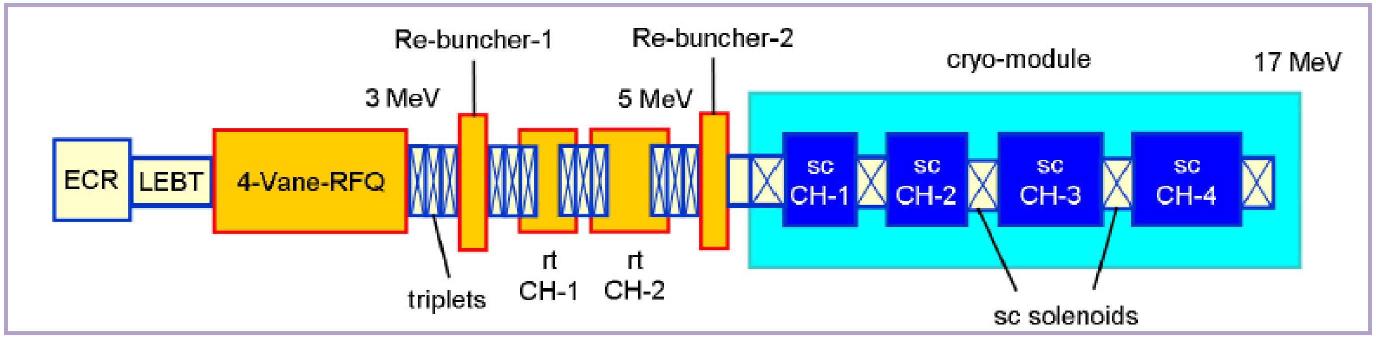


Figure 9: Layout of the superconducting 325 MHz CH-cavity with helium vessel.



Superconducting multigap CH cavity

Gap number	19
Length (mm)	1048
Frequency (MHz)	360
β	0.1
E_p/E_a ($\beta\lambda$-definition)	5.2
B_p/E_a [mT/(MV/m)]	5.7
$G=R_sQ_0$ (Ω)	56
R_a/Q (Ω) (T incl.)	3180
$(R_a/Q)G$ (Ω^2)	178000
Q_0 (BCS, 4.2K, 360 MHz)	1.5×10^9
Q_0 (total R_s=88 nΩ)	6.8×10^8
W [mJ/(MV/m)^2]	92

+ Very efficient

+ large energy gain

+ feasible also for very low β

- β acceptance

- Difficult to have large aperture

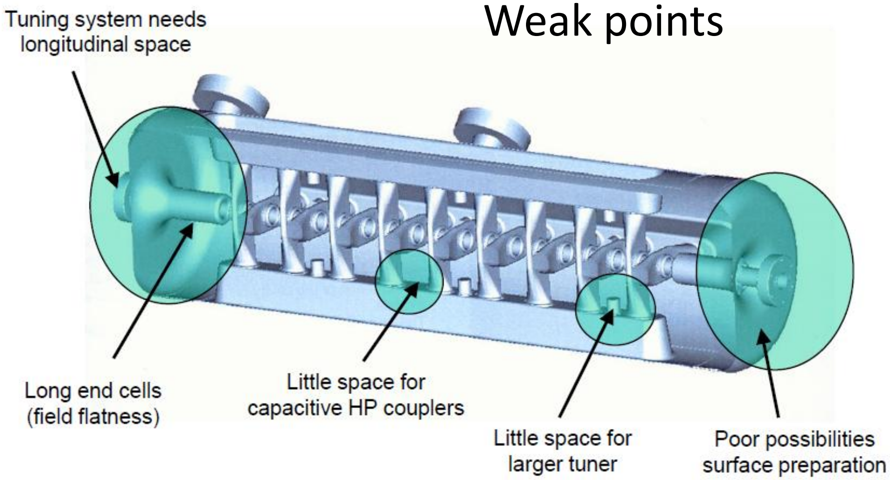
- not easy to build and tune

-**cost (…but possibly good cost/MV in a linac)**

- **essentially non-linear longitudinal motion**

Tested – 7 MV/m

Weak points



Two attempts of RF focusing in SC cavities

RF-FOCUSED SPOKE RESONATOR
R. W. Garnett et al, LANL

β=0.125, f=350 MHz,

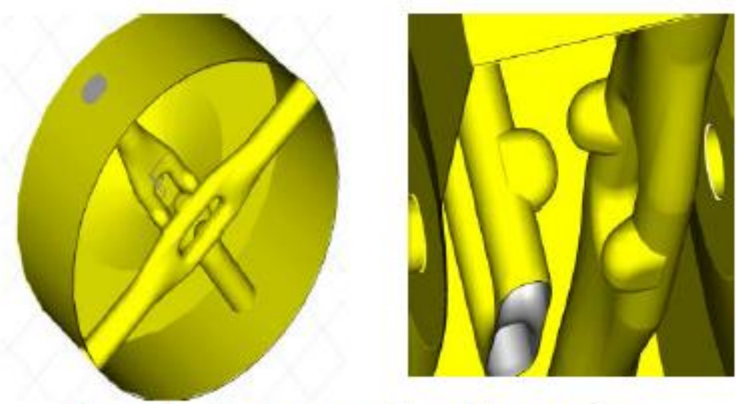


Figure 1 - Spoke geometry cut-away views.

Slot-finger superconducting structure with rf focusing
Yu. Senichev and N. Vasyukhin
FZJ, Juelich, Germany

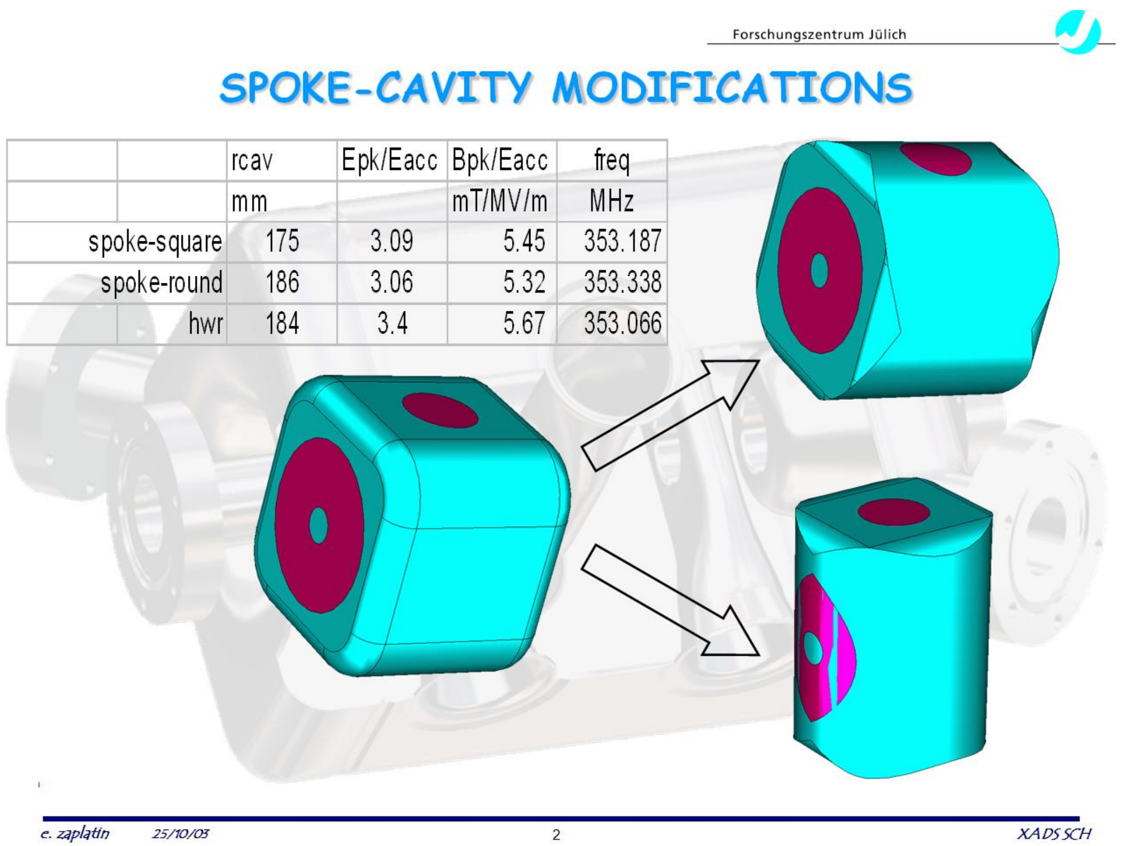
From 3 MeV, f=352 MHz, 15 MV/m

FIG. 4. (Color) Slot resonator in 3D.

Conclusion

- Today: HW coaxial resonators
- Tomorrow: HW spoke resonators
- Future: Multigap CH?, RF focusing?

Transition from HW to spokes should be smooth – essentially they are the same:



		rcav	Epk/Eacc	Bpk/Eacc	freq
		mm		mT/MV/m	MHz
spoke-square		175	3.09	5.45	353.187
spoke-round		186	3.06	5.32	353.338
hwr		184	3.4	5.67	353.066

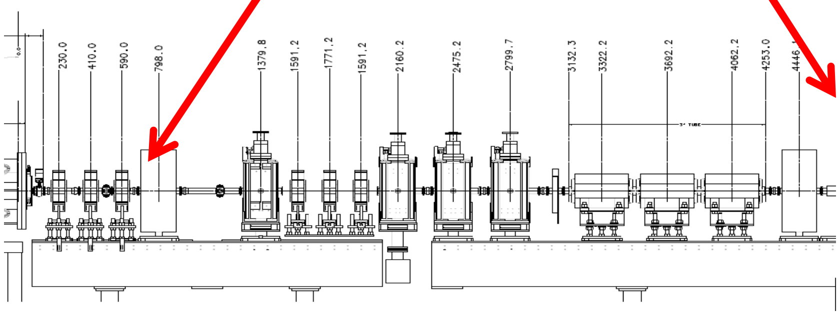
The simplest, but not very informative

The danger of beam is that it’s a source of secondary emission and dark currents, it’s a source of breakdowns. We can check how SSR1 feels with beam inside without acceleration .

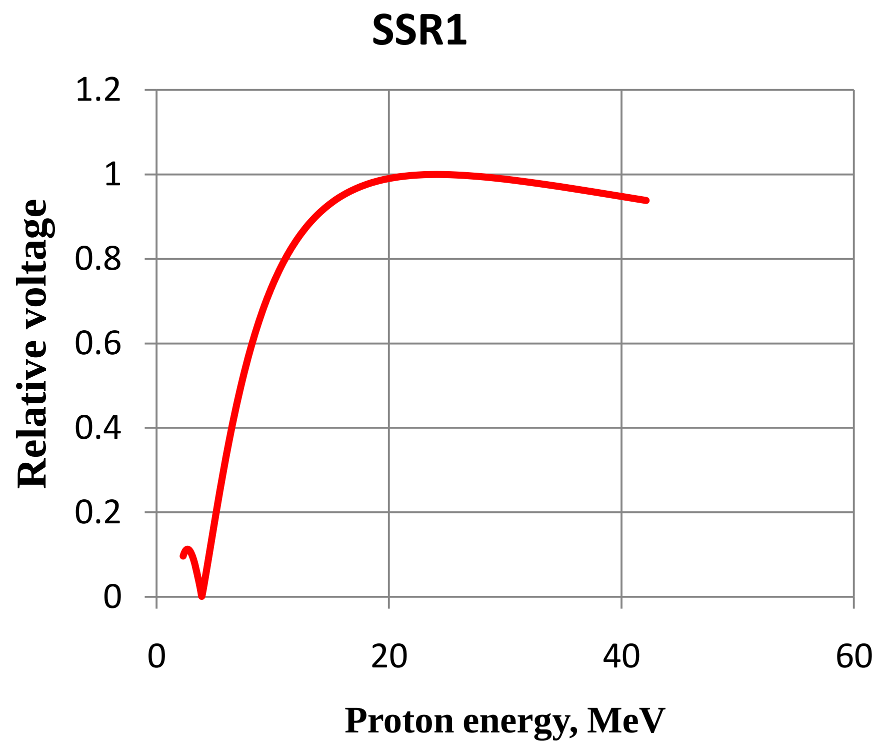
SSR1 cryostat

Here

Or here



It’s better to move to 10 MeV as closer as possible



Preliminary TRACK simulation of SSR1 cryostat test